# National Bureau of Standards

# TECHNICAL NEWS BULLETIN


VOLUME 36 JANUARY 1952 NUMBER 1



# Cathodic Protection of Steel Underground

UNDERGROUND corrosion of steel pipe has been estimated to cost 600 million dollars annually in the United States. Efforts to reduce this toll have been stimulated since 1941 by heavy defense requirements for steel and other metals. Workers in the field have learned that underground corrosion can be greatly reduced by cathodic protection techniques, in which the structure is maintained at a suitable negative electrical potential.

A recent study by W. J. Schwerdtfeger and O. N. McDorman of the NBS corrosion laboratory provides a better understanding of the mechanisms of this important method of inhibiting underground corrosion. The NBS study centered around laboratory determination of the optimum potential to be maintained for effective protection. By eliminating uncertainties inherent in field measurements, NBS was able to determine an optimum protective potential having a firm scientific basis. The value arrived at ($-0.77$ volt referred to a saturated calomel electrode) was confirmed by weight-loss measurements on electrodes maintained at the selected potential in five corrosive soils.

Normal corrosion of iron and steel underground is largely an electrolytic phenomenon. When iron is exposed to the soil, local differences in electrical potential develop at the surface of the metal, resulting in the formation of numerous small corrosion cells. This means that electric currents flow through the soil from certain areas (anodes) to areas of less negative potential (cathodes), with accompanying loss of metal from the anodes and evolution of hydrogen at the cathodes. When cathodic protection is applied, direct current from an external source is caused to flow through the soil from an auxiliary anode toward the corroding surface. This applied current causes the cathode potentials to approach the anode potentials and thus reduces the corrosion currents.

The question of the potential at which an underground structure should be maintained in order to inhibit corrosion is of considerable interest. Insufficient potential will give inadequate protection. On the other hand, maintaining a greater potential than is needed is unnecessarily costly, since this requires supplying a larger external current through the earth.

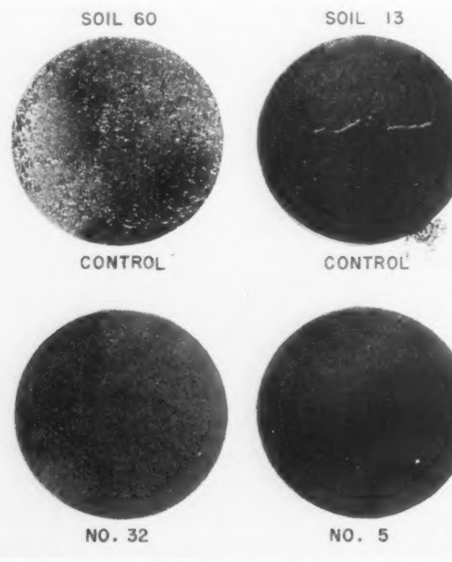
When the potential of a cathodically protected underground structure is measured in the field, an indefinite *IR* (voltage) drop is ordinarily included in the measurement. The magnitude of this drop at a given value of current naturally depends upon the conductivity of the soil and the position of the reference electrode used in making the measurement. Corrosion circuits are complex, and there is no general agreement among engineers as to where the reference electrode should be located. A measured value of $-0.85$ volt (referred to a standard copper-copper–sulfate electrode) is generally accepted by engineers as the optimum protective value. Yet because the amount of *IR* drop is not ordinarily known, identical readings of $-0.85$ volt at different installations are not likely to indicate the protective potential free of undesired *IR* drop.

These uncertainties were eliminated in the NBS laboratory in arriving at the value of $-0.77$ volt referred to a saturated calomel electrode. Since this value corresponds approximately to $-0.85$ volt referred to the copper-copper–sulfate electrode, the NBS work confirms the practice of cathodic-protection en-

gineers for the special condition when all *IR* drop is eliminated except that which is included in the field of the normal corrosion circuits.

To arrive at the optimum protective potential for steel in soils, the potentials of steel electrodes were measured at NBS in 20 air-free soils, ranging from very acid (pH 2.9) to very alkaline (pH 9.6). Potentials were plotted against the pH values of the soils. The resulting curve intersected the potential curve for the standard hydrogen electrode at a pH of approximately 9 and a potential of −0.77 volt (referred to a saturated calomel electrode). This potential was also approximately the most negative value measured. At more negative potentials iron becomes cathodic to the hydrogen electrode, and corrosion therefore ceases.

To confirm experimentally the effectiveness of a −0.77-volt protective potential, weighed steel electrodes were exposed to five soils in specially designed corrosion cells. After 2 days without protective current, the electrodes were maintained at −0.77 volt for 60 days. By making potential measurements with an electronic interrupter in conjunction with a potentiometric measuring circuit, all *IR* drop external to the boundary of the corrosion circuit was eliminated. Weight lost during the test by the electrodes maintained at −0.77 volt was negligible compared with weight losses of control electrodes that received no current. Electrodes allowed to deviate for relatively short periods to potentials less negative than −0.77 volt lost appreciable weight, but electrodes maintained at more negative potentials (−1.0 volt) did not show appreciably greater reduction in weight.




**In studies to determine scientifically the optimum protective potential for the cathodic protection of iron and steel underground, steel specimens were exposed to corrosive soils, including a very acid soil, pH 2.9 (left), and a very alkaline soil, pH 9.5 (right). Control specimens (upper) received no protection; others (lower) were maintained with an applied protective potential.**

**TECHNICAL NEWS BULLETIN**

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Charles Sawyer, *Secretary*
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A. V. Astin, *Acting Director*

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## Contents



The current required to maintain a −0.77-volt protective potential is not uniform. With most of the soils tested the necessary current diminished to a fairly stable value after about 3 weeks. These minimum values of current needed to maintain the protective potential differed for different soils, and were approximately equal to the average corrosion currents calculated from weight losses of the control electrodes.

It was possible to estimate the minimum protective current initially required for cathodic protection in a particular soil by preliminary measurements. Electrode potentials were measured as increasing values of current were applied. The potential-current curve given by these measurements has a characteristic change in slope at a certain current value, above which the potential changes more rapidly. The current indicated by the change in slope was taken to be the minimum value initially required for effective protection. This current, when constantly applied, caused the electrode potential to drift to the protective value (−0.77 volt) in from 3 to 21 days as alkali accumulated on the electrode surface.

Prior to disassembling the corrosion cells, the protected electrodes were left without protective current for about 15 hours, after which a curve relating potential to applied current was again obtained. This time the change in slope, characteristic of corroding metals, was no longer evident. This was taken as a further indication of the effectiveness of the protection against corrosion furnished by the −0.77-volt potential.

*For further technical details, see* Potential and current requirements for the cathodic protection of steel in soils, *by W. J. Schwerdtfeger and O. N. McDorman, J. Research NBS* **47**, *104 (1951) RP2233.*

# Simplified Radioactivity Survey Instrument

The rather expensive and fragile moving-pointer microammeter generally used to indicate radioactivity levels is eliminated in the NBS radioactivity survey instrument. Instead, the level of radiation is read from a calibrated potentiometer dial.

PORTABLE self-contained radioactivity survey instruments of the gamma type generally use a microammeter to indicate the radiation level. Ideally these survey instruments should be low in cost as well as compact and rugged. Yet microammeters are inherently neither cheap nor rugged, nor are they suited to mass production in extremely large volume. A new gamma survey instrument, recently developed by S. R. Gilford and S. Saito of the NBS electronic instrumentation laboratory, requires no microammeter.

In the NBS instrument, which was developed for the Navy Bureau of Ships, radiation levels are read directly from a potentiometer dial. To read an unknown value of radiation, the operator turns the dial to the point at which an audio oscillation just begins. This point is determined aurally with the small earphone that is standard equipment for most survey instruments. This aural indication is particularly convenient for plotting contours of equal radioactivity; with the dial set for a particular radiation level, it is an easy matter for the operator to walk along and locate aurally a series of equally radioactive points.

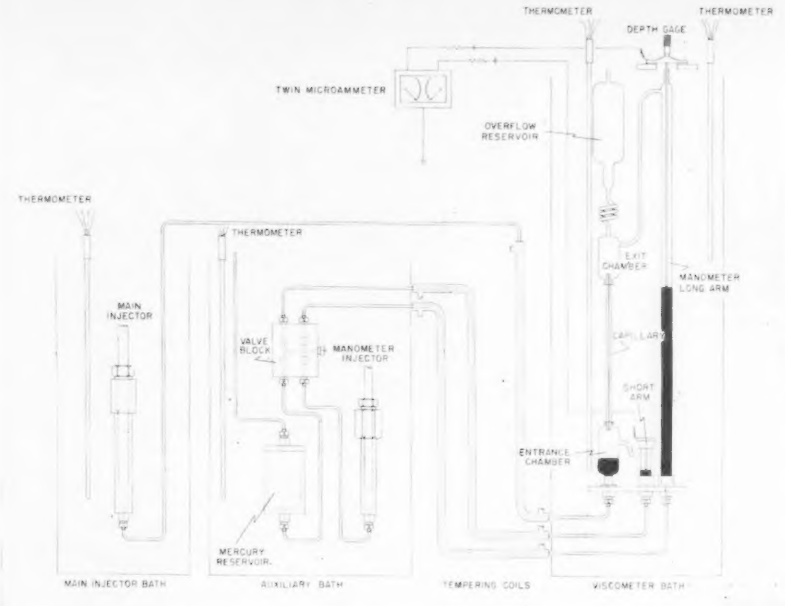
Like many other gamma-radiation survey instruments, the NBS device uses a detector tube of the halogen-filled Geiger-Müller type, together with a vibrator high-voltage power supply operating from flashlight-type batteries. Output current of the detector is proportional to the incident radiation.

The heart of the aural indication method is a thyratron relaxation oscillator circuit. If the potential difference between the grid and cathode of the thyratron exceeds the firing potential, the circuit will oscillate. The unknown voltage derived from the detector tube current is applied to the outer terminals of the potentiometer, while the thyratron grid is connected to the moving contact. The potentiometer setting at the threshold of oscillation thus depends on the radiation level, and the potentiometer dial can be calibrated directly in radiation units.

# Absolute Viscosity of Water at 20° C

A DETERMINATION of the absolute viscosity of water at 20° C with greater accuracy than ever before attained has recently been completed by J. F. Swindells of the Bureau staff. The new value is 0.01002 poise (dyne-seconds per square centimeter) as compared with 0.01005 poise, which has been generally accepted up to the present time. The absolute viscosity of water serves almost universally as the standard to which the viscosities of all other liquids are referred. Beginning July 1, 1952, the Bureau will use the new value as the primary standard for calibrating viscometers and for evaluating secondary standards that are issued as viscometer calibrating liquids. It is recommended that, in so far as possible, this change be adopted generally at the same time.

The determination was made by the method of capillary flow. The laws governing laminar flow through an infinitely long capillary are well understood; the only difficulty in their practical application is evaluation of the deviations from the laws that are peculiar to the flow at the ends of a capillary of finite length. However, by the simultaneous treatment of flow data obtained in two capillaries of the same diameter but different lengths, the effects of the ends of the capillaries may be eliminated. The flow data are obtained by inducing a known rate of flow of water in each capillary by means of a calibrated piston and accurately measuring the corresponding pressure drop across the capillary. These measurements, together with the dimensions of the capillaries, give the quantities necessary for calculation of the viscosity.




**By means of a calibrated piston, water is caused to flow at various rates through selected capillaries of known dimensions. As the water flows through a capillary, viscous resistance causes a liquid pressure drop that is accurately measured with a differential mercury manometer.**

The capillaries for the present work were carefully selected by optical means for roundness and uniformity of bore from Fish-Schurman Precision-Bore glass tubing. Diameters of about 0.05 and 0.04 centimeter were used, starting with a length of about 50.0 centimeters. Following flow tests, these tubes were cut approximately in half, giving capillaries of shorter length but essentially the same diameter. The ends of the capillaries were then ground and polished flat and parallel and their lengths measured directly with suitable gages. Two methods were employed for the determination of the mean diameter of each tube. In the first method the diameter was calculated from the weight of mercury required to fill exactly the capillary bore. In the second, the electrical resistance of a column of mercury filling the bore was measured, and the diameter was calculated from the known resistivity of mercury. Values obtained from both methods were in good agreement.

For the flow tests, the capillary was mounted between two relatively large glass terminal bulbs by means of ground joints. Water columns transmitted the pressures in the bulbs to the arms of a differential mercury manometer. The heights of mercury in the manometer were measured from a fixed surface plate by means of pointed depth-gage rods mounted in a micrometer head. Contact of the rods with the mercury surface was determined electrically by passing a weak current at low potential through the mercury and the gage rod and observing the indication of contact between the rod and mercury surface with a microammeter. The viscometer and manometer were mounted together in a large oil bath in which the temperature was maintained within about $\pm 0.001^\circ$ C of the desired $20^\circ$ C.

The various known rates of flow were induced in the capillary by injecting mercury into the terminal bulb at the entrance end of the capillary at known constant rates, displacing the water through the capillary. The mercury was injected by means of an accurately ground and lapped piston driven at a uniform rate through suitable gears by a synchronous motor operating on a controlled-frequency source of current. The desired rates of flow were obtained by choosing proper gear combinations. The delivery rate of the piston was calibrated by weighing quantities of mercury displaced by the travel of the piston through a number of increments of its stroke. From such data the mean rate, as well as variations in the rate, of displacement of mercury by the piston were determined. The injector piston was thermostated in an oil bath to eliminate the effect of temperature variation on its rate of delivery.

Flow measurements were obtained with four capillaries, identified as follows:

| Capillary designation | Nominal dimensions | |
|---|---|---|
| | Diameter | Length |
| | *Cm* | *Cm* |
| 2.5 | 0.05 | 49 |
| 2.5a | .05 | 24 |
| 1.4 | .04 | 45 |
| 1.4a | .04 | 23 |

In order to minimize any uncertainties introduced by the effects of the ends of the capillaries or by inaccuracies in measuring their diameters, the calculations were made using the flow data for the capillaries in the four possible combinations of pairs involving a long and a short capillary. The final result obtained from these data is 0.010019 poise with a standard deviation of ±0.000003.

*For further technical details, see* The absolute viscosity of water at 20° C., *by J. F. Swindells, J. R. Coe, and T. B. Godfrey, J. Research NBS* **48,** *(Jan. 1952) RP2279.*

| Pair | Viscosity | |
|---|---|---|
| | Observed | Mean |
| | *Poise* | *Poise* |
| 2.5 and 2.5a ........ | 0.010022 | 0.010018 |
| 1.4 and 1.4a ........ | .010014 | |
| 2.5 and 1.4a ........ | .010022 | .010020 |
| 1.4 and 2.5a ........ | .010018 | |

# NBS Telemetering-in-Flight Calibrator

A 10-CHANNEL in-flight calibrator recently developed by the Bureau utilizes a unique system of cam-operated switches that eliminates many of the difficulties encountered in calibrators of comparable size and scope. Designed to identify telemetered information from a guided missile in flight, the device is compact, durable, and particularly suited to telemetering applications in aircraft, missiles, or projectiles. The initial model, which was designed by L. L. Parker and W. A. Hereth of the NBS guided missiles laboratory, is now being manufactured by the J. P. Seeburg Co.

Telemetering involves the measurement of one or more quantities by electrical instruments, the transmission of the data to a distant receiving station, and the receipt and recording of the measured quantities. The information is usually transmitted by radio, although under some circumstances it may be carried by wire. The transmitted signals may be derived from transducers or pickups, that translate mechanical movement into electrical impulses, or they may be derived through direct coupling to electric circuits. Normally, the information is then used to modulate a high-frequency radio carrier.

At the receiver-recorder it is virtually impossible to assign any finite value to the received information until two or more reference levels of modulation have been established in terms of the response of the receiving equipment. The NBS in-flight calibrator sequentially supplies each intelligence channel with four known levels of modulation. Thus, the telemetering record is provided with known reference levels of modulation from which the received data may be interpreted.

Transmission control of the calibrating signal, as well as the "data" signal, is achieved through the action of two groups of noise-free switches involving 40 separate switching operations. The first group contains 10 single-pole double-throw switches operated in sequence by a motor-driven cam. Its function is to interrupt briefly and periodically the normal channeling of the operating information to the r–f transmitter and to connect the calibrating circuit to the output, instead.

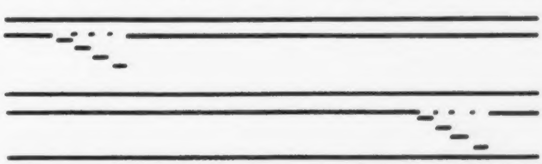
The second switching-group contains four single-pole single-throw switches, also operated by a motor-driven cam. The function of this group is to pass step-calibrating signals sequentially to the transmitter during the interval in which a particular telemetering channel is interrupted by the first group of switches. The step-calibrating cam cycles 10 times (four modulating signals with each cycle) for each cycle of the channel-interrupting cam; each interrupted channel receives identical calibrating signals.

All switches and cams are contained within a cylinder about 2 inches long and 4 inches in diameter. The drive motor for both cams is mounted at one end of the calibrator.

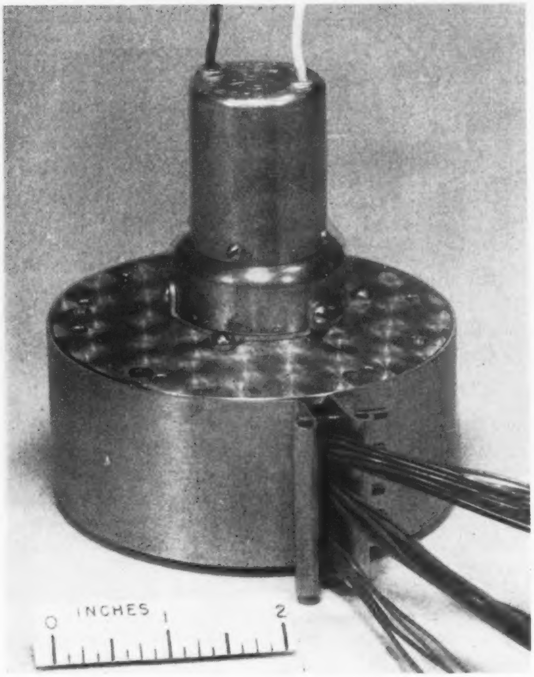
The NBS in-flight calibrator could easily be expanded to permit operation of 20 telemetering channels. This would simply involve installing 10 more switches, increasing the width of the slow-speed cam, and enlarging the calibrator housing to accommodate the additional switches. Such an arrangement would permit two channels to be calibrated simultaneously; each channel would be recalibrated every 10 calibration cycles.

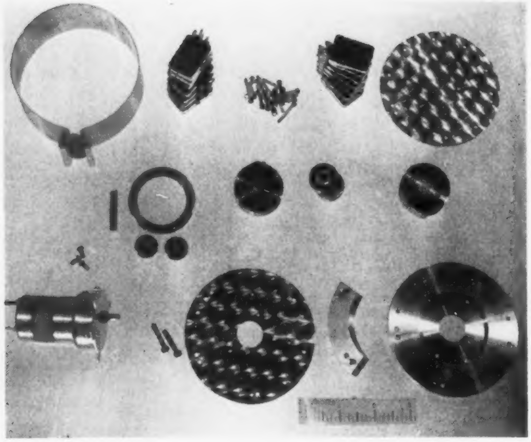
The four reference calibration levels supplied by the NBS calibrator to the transmitter are usually chosen so as to divide the total modulation range into equal parts on the record. Thus, the traces of the calibration signals not only form a basis for assigning calibration values to the record but also provide a means for correcting for any nonlinear qualities of the transmitter and receiver-recorder.

Other useful functions are served by the calibrator. In some recording systems it is desirable to increase



**The automatic reeceiver-record of intelligence from a guided missile transmitter shows signals from several channels as comparatively straight lines. Each is sequentially interrupted with four step-calibrated signals from the NBS telemetering-in-flight calibrator. The calibrated steps are used to measure the absolute value of the telemetered information.**



**The step-calibrating signals of the NBS telemetering-in-flight calibrator (left) are provided by switches that interrupt the normal channeling of telemetered information. These are activated sequentially by a slow-speed cam and a high-speed cam. Components (above) include (left to right, top row): Cover, switches, end plate; (center) drive shaft, internal gear and planet gear assemblies, high-speed cam, bearings, low-speed cam assembly; (bottom) drive motor, motor mounting plate, spacer, gear housing.**

the sensitivity of the telemetering receiving equipment to such a degree that adjacent recording traces overlap; the sequential nature of the NBS calibrator then serves to identify the separate traces, which may become confused because of the many cross-over points. The mechanism is also useful in applying modulation to the telemetering transmitter during preflight adjustment and checkout. In effect, the calibrator simulates the information normally translated by the transducers and thus permits regulation and testing of the transmitter-receiver system prior to actual flight.

The NBS in-flight calibrator performs satisfactorily under a wide range of drive-motor speeds; however, the optimum speed for in-flight operation of the high-speed cam is around 200 rpm. To prolong the life of the components, it is desirable during pre-flight adjustment to operate the in-flight calibrator at a lower speed of about 60 rpm.

# Suppression of Microwaves by Zonal Screens

A METHOD for alleviating one of the difficulties confronting the users of line-of-sight microwave communications—service interrruptions resulting from ground-reflection effects—has recently been devised by the Bureau through the application of optical methods and theories to microwave techniques. In particular, a method based on the classical Huygens-Fresnel diffraction theory has been developed by H. E. Bussey of the NBS staff for the suppression of the ground-reflected waves that are present in microwave radio relay link operations.

Interruptions in line-of-sight microwave communications may occur when the direct wave from the transmitter and the ground-reflected wave destructively interfere with each other at the receiver. Although it is possible to set the receiver at a point of constructive interference, subsequent atmospheric changes usually shift the spatial interference pattern (the so-called lobe pattern) of the source and its image sufficiently so that an interference minimum frequently occurs at the receiver.

In the NBS method reflected-wave suppression is achieved by setting a small screen of the proper size on the ground at the "reflection point" in the path. The reflected wave at the receiver is then substantially diminished, to an extent depending on the smoothness of the ground plane. The screen is designed to block only a small part of the reradiation from the ground to the receiver; the remainder of the reflected radiation adds up to zero at the receiver. The direct wave undergoes little or no modification during the suppression of the ground-reflected wave.

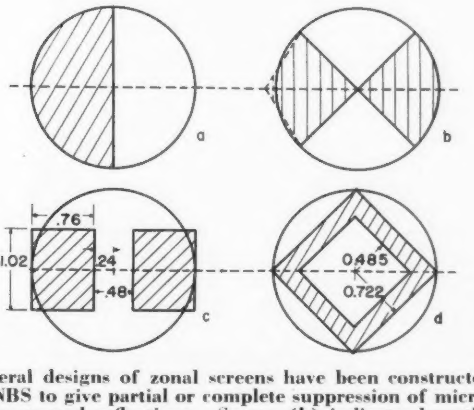
The NBS wave-suppression technique is based on the optical principle that the wave field transmitted from a point source to a point receiver under free-space conditions becomes zero if half of the first Fresnel zone

is blocked so that the remaining diffracted contribution of the zone is halved in amplitude and unchanged in phase. The reduced contribution of the first zone is then cancelled by radiation from unblocked zones.

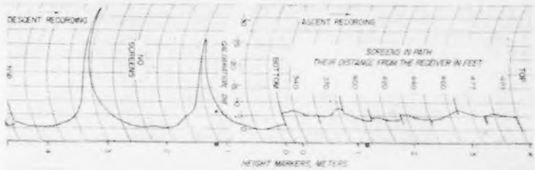
One of the screens developed by NBS takes the form of an opaque quarter-circle. The screen is erected on the ground at a point along the transmission path where the reflected ray from the transmitter strikes the ground. The plane of the screen is perpendicular to the path, and its radius is equal to that of the first Fresnel zone in this plane. Thus, the quarter-circle blocks one-half of the first Fresnel zone for the ground-reflected wave; according to optical theory, the remaining contribution from this zone is cancelled and the effect of the image source is effectively eliminated at the receiver. There is also a large area surrounding the receiver position in which the effect of the image is nearly eliminated; consequently there will always be at least a partial suppression of the reflected wave at the receiver as meteorological fluctuations vary the position of the image source.

To obtain experimental confirmation of the reflected-wave suppression, the NBS investigators used a 4,500-megacycle transmitter. Horizontally polarized signals were radiated from a 4- by 6-inch horn set about 14 feet above the ground. The receiving antenna was an exact duplicate of the transmitting horn. The receiving antenna was located about 800 feet from the transmitter and could be raised and lowered on a 50-foot tower. The received power was recorded as a function of this variable height.

One of the NBS experimental wave suppressors is composed of two triangular screens with edges of 7.3, 6.6, and 5.4 feet. When the path was not obstructed by the suppressor, the receiver recorded a well-defined interference pattern of minimum and maximum signal




**Several designs of zonal screens have been constructed at NBS to give partial or complete suppression of microwave ground reflections. Screen (b) indicates how the semicircular screen (a) can be cut into subsectors. Screen (c) is composed of two rectangles that are structurally convenient and produce a broad null area. Screen (d) offers a convenient variation for isolated application in which permanent structures may be utilized.**




**A receiver-recording of signal strength versus height and time of a microwave radio relay shows a well-defined pattern created by the interference of the reflected ray when no screen is placed in the path and the receiver descends from 4 meters. When two triangular screens are placed in the path, the influence of the reflected wave is largely eliminated at the receiver as it ascends to 4 meters.**

strengths as the receiving antenna was raised and lowered on the tower. But when the triangular screens were placed in their proper position, the influence of the reflected wave was substantially eliminated at the receiver. The field strength of the remaining direct wave was 6 decibels less than that of the signal at a point of maximum interference when no suppressing screen was used. By moving the receiving antenna above and below its normal operating position in search of any nearby reflected-wave interference, it proved to be possible to determine whether the reflected wave was really suppressed or merely shifted in phase.

In practice, microwave radio relay paths are usually about 20 or 30 miles long, and the transmitters generally operate at a frequency of about 4,000 megacycles (wavelength 7.5 centimeters). Under these conditions, the first Fresnel zone is 80 to 100 feet in radius at the middle of the path, and the radius of the main suppressed area at the receiving point is about 8 to 10 feet. Fortunately, the antennas commonly used for microwave relay transmissions are about 8 feet in radius. To accomplish nearly complete suppression, the screen is positioned on the path to within a few feet of the center. Because the direct wave is diffracted, perfect suppression cannot be obtained in any instance, and some error in locating the screen can be tolerated. For a first zone of 80 feet, a satisfactory screen is a rectangular structure made of hardware cloth and mounted on poles 40 feet high.

A number of NBS experiments using differently shaped screens have substantially confirmed the Bureau's application of optical theory to microwave techniques. They have indicated that troublesome ground reflections can be eliminated by small screens erected in the path, or when technically feasible, by utilizing obstacles permanently located near the proper position in the path.

*For further technical details, see* Reflected wave suppression, *by Howard E. Bussey. Proceedings of the IRE,* **38,** *No. 12, 1453 (1950).*

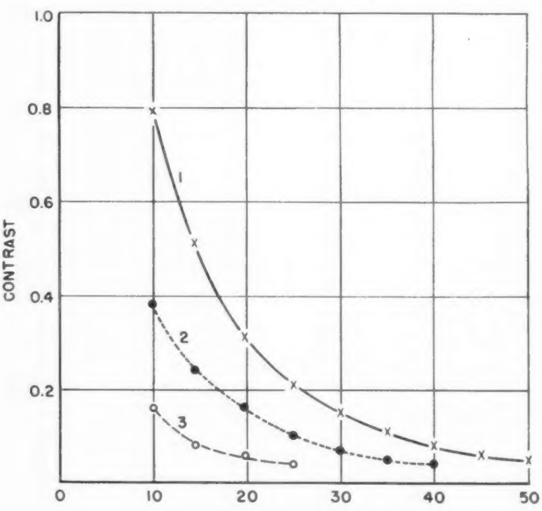
*The substance of this article was presented before the Joint IRE-URSI meeting held in Washington, D. C., April 1951.*

# New Resolving Pow

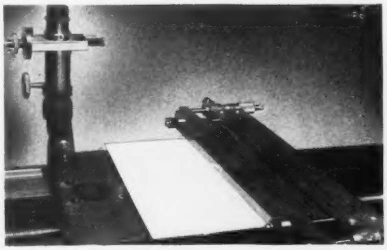
THE RESOLVING power of photographic lenses can now be more effectively measured and studied by means of a variable-contrast test chart recently developed by I. C. Gardner, F. E. Washer, and F. W. Rosberry of the Bureau's optical instruments laboratory. The new chart enables the user to obtain in a single photograph a complete record of the resolution characteristics of a lens for any value of target contrast in the range from 0.0 to 1.5. Resolving power can thus be measured for both high and low contrast without changing experimental conditions, and the relationship between resolving power and contrast can be systematically investigated. Although the chart was developed primarily to measure the characteristics of aerial mapping cameras, it should be of value to makers and users of all types of photographic equipment.

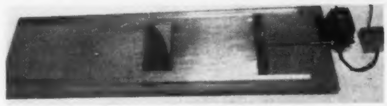
Requirements for aerial camera lenses are very exacting: the lens must have good resolving power and little or no distortion over the entire field. As a result of research conducted by NBS since World War I, largely for the military services, precise methods for measuring and specifying distortion and focal length have been developed. Determination of resolving power, however, has remained something of a problem.

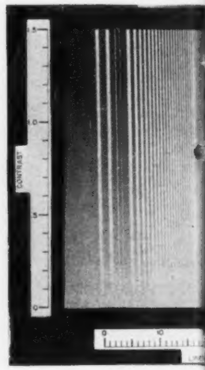
The method now in general use for designating the resolving power of a photographic lens is based on an evaluation of the image that the lens forms of a high-contrast resolution chart. This chart contains patterns of parallel lines having various spacings. As the contrast between lines and spaces is higher than that usually found in natural objects, it has been suggested that a test made with this chart may not be applicable to the




**Contrast has been measured at three different heights (1, 2, and 3) on the variable contrast resolving power chart with pan process emulsion when testing a lens having a focal length of 127 millimeters and set at an aperture of *f*/8 (gamma=1.2).**







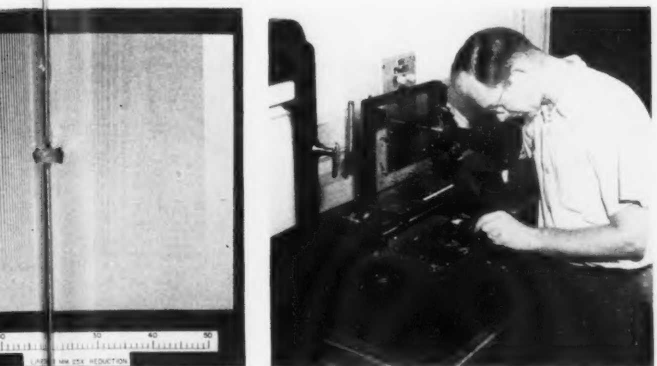

**For making the variable contrast resolving power chart, a ma er high a series of slits whose width is varied (upper left) according a defin holder of the special apparatus (lower left) and the master h h-contra the curved diaphragm once across the plate, the negative is moved, moved across the plate. After processing, the plate become he fini various parts of the chart is determined by the densitometer ( ght), wh adjacent dark and light areas.**

conditions under which the camera is used. NBS therefore developed a test chart that would simultaneously measure the resolving power of a lens and show the variation of resolving power with contrast. The resulting chart has been found very successful in application and is being recommended for adoption as an international standard.

The new test chart consists of a series of long parallel lines so arranged that the widths of successive lines and of the spaces separating them progressively decrease. The "instantaneous" value of the number of lines per millimeter is a linear function of the distance from the first, or broadest, line. At the same time, the transmittance of the lines and spaces varies from end to end in such a way that the contrast at any place in the chart is a linear function of the distance, measured parallel to the lines, from one edge of the chart; and the transmittance of the chart averaged over an area embracing several pairs of lines and spaces is uniform for the entire chart. The long lines of the chart make it especially suitable for microphotometric examination of the final test images, thus making possible a more objective determination of resolving power.

Two steps are involved in making the NBS chart. First, to insure a continuous variation in contrast, a negative of the high-contrast master chart is contact-printed onto a photographic plate while the exposure time is varied over the plate in a predetermined manner. In the second step, the high-contrast chart is removed, and the photographic plate is again exposed in

# g Power Test Chart



a ma er high-contrast negative is first prepared by exposing it under ling a definite pattern. A photographic plate is then placed in the ter h h-contrast negative placed over it. After the motor has driven e is moved, the plate turned through 180°, and the diaphragm again come he finished variable-contrast chart (center). The contrast at ter ( ght), which measures the difference in photographic density of

such a manner that the transmittance averaged over several lines of the finished negative is a constant.

To carry out this two-step process, a device was constructed in which a motor moves a specially shaped diaphragm across the partially exposed plate at constant speed. The photographic plate is placed in the holder of the device, emulsion side up, and the master high-contrast negative is placed over it. A small light source is located about 8 feet above the travelling diaphragm. After the diaphragm has traversed the plate once, the high-contrast negative is removed, the photographic plate is turned through 180°, and the diaphragm is again made to traverse the plate at constant speed. The double-exposed plate is then processed, and the finished negative is the final variable-contrast chart.

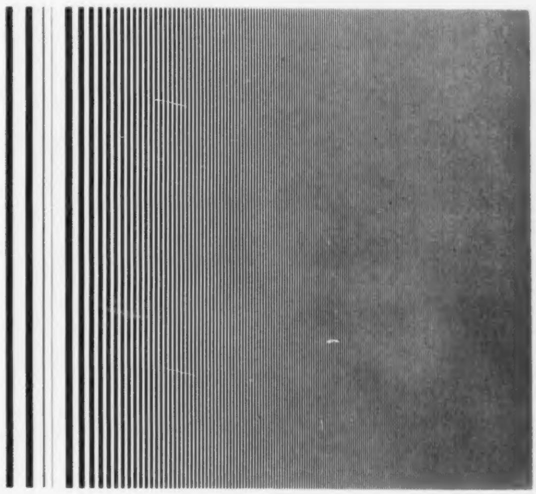
This chart is illuminated and used as a "target" for image formation by the lens under test. Information on resolving power can then be obtained from measurements made on a photograph of the image thus formed.

As the chart is constructed, the contrast is approximately constant along any line drawn perpendicular to the lines and spaces of the chart. However, the variation in contrast in the photograph of the image will ordinarily be somewhat different from the variation in contrast in the target. In both cases the contrast progressively decreases along any one of the dark lines, but in the image the rate of decrease will be greater along some of the lines than along others. Any decrease in contrast may be the result of the particular combination of lens and photographic emulsion used.

Ideally, it should be possible to obtain the maximum resolving power of the lens under test by determining the line frequency at which the contrast in the image of the target becomes zero. However, at the present stage of the development, local irregularities in the image make it impossible to state with certainty just when the contrast in the image reaches zero. For this reason, the performance of a lens is reported in terms of the resolving power, or line frequency as read from the chart, for a selected value of contrast in the image, a specified value of contrast in the image, a specified value of contrast in the target, and a specified type of photographic emulsion. It is believed that the new test chart will prove extremely useful for studying the manner in which contrast in the image is affected by contrast in the object, lens action, and granularity of emulsions.

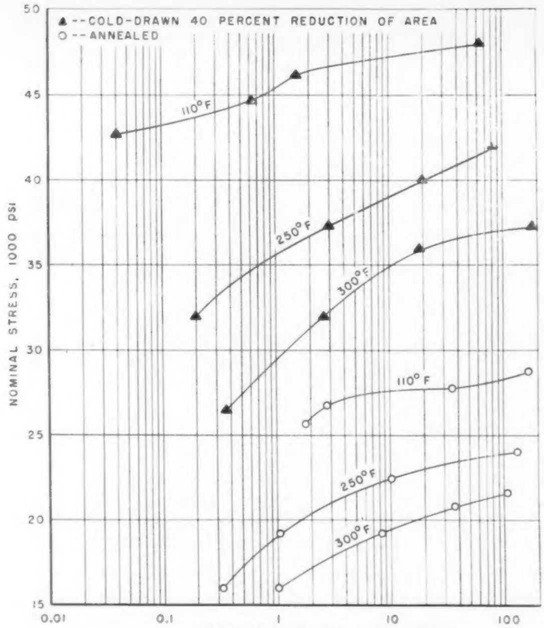
In the course of the investigation, striking examples of "false resolving power" were found when the original high-contrast master chart was used as a target. It was discovered that this effect was caused by overlapping of the out-of-focus images of elements of the target. In testing lenses, the possibility of such spurious resolution should not be overlooked. Because of the curvature of the field, some portion of the photographic plate is almost sure to be out of focus—and quite possibly by enough to cause false resolution.

*For further technical details, see* New resolving power test chart, *by F. E. Washer and F. W. Rosberry, J. Opt. Soc. Am.* **41**, *597 (1951). See also* A new resolving power test chart, *by I. C. Gardner, J. Opt. Soc. Am.* **40**, 257 (1950); *and* Spurious resolution of photographic lenses, *by Robert N. Hotchkiss, Francis E. Washer, and Fred W. Rosberry, J. Opt. Soc. Am.* **41**, *600 (1951).*



**Master high-contrast test chart used in preparation of the new variable-contrast chart illustrated above. The range of the chart is from 0.2 to 2.0 lines per millimeter.**

# Creep of Cold-Drawn High-Purity Copper

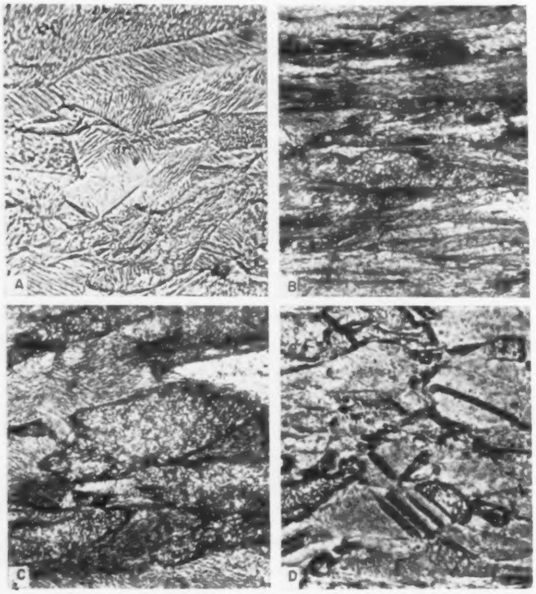



**Relation between stress and average second-stage creep rate of high-purity copper at different temperatures. The resistance to creep of the cold-drawn copper even at 300° F. is considerably higher than that of the annealed copper at 110° F.**

INVESTIGATION at the National Bureau of Standards of the creep of high-purity copper has recently been extended to include cold-drawn copper. In an earlier phase of the same program, NBS studied creep characteristics of oxygen-free high-conductivity (OFHC) copper in the annealed condition. The present work utilized samples of the same lot of copper, as cold-drawn to 40-percent reduction in area. William D. Jenkins and Thomas G. Digges of the NBS thermal metallurgy laboratory conducted the studies. Specimens were tested for their creep characteristics at 110°, 250°, and 300° F with constant loads in tension.

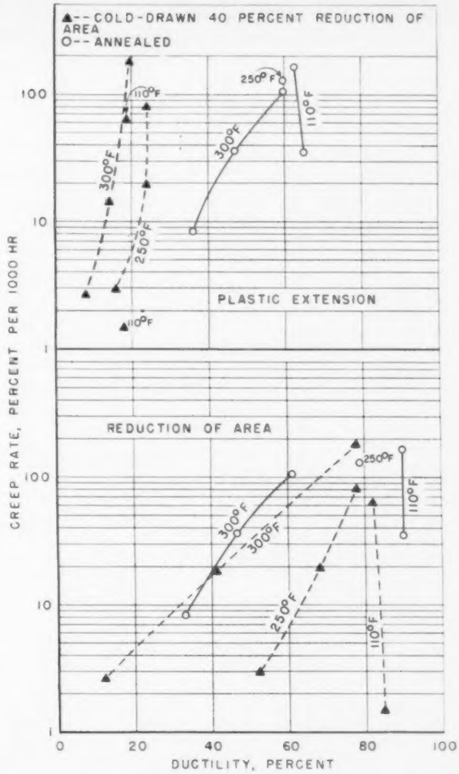
A valuable and useful property of ductile metals is their ability to become stronger and harder by cold-drawing or other cold-working. This increase in strength is usually accompanied by a decrease in toughness, especially when specimens are tested in tension at the same temperature as that used in cold-working. However, there are some exceptions to this general behavior: for example, cold-working of austenitic stainless steel may increase both its strength and its ductility in tension at extremely low temperature. Also, the superiority of the cold-worked metal is not necessarily maintained in applications at elevated temperatures for long periods of time; recrystallization and recovery are then likely to be predominant factors.

In general, creep—in terms of extension-versus-time under constant load—goes through three stages (after an initial extension that occurs on application of the load). The first stage is one of decreasing rate of extension. Then, in the second stage, creep proceeds at a nearly constant rate. The third stage is one of increasing rate, culminating in complete fracture.




**Photomicrographs showing effect of testing conditions on structure: (*A*) Cold-drawn 40-percent reduction in area, not tested in creep; (*B, C, D*) tested with creep rate of about 2 percent per 1,000 hours at 110° F. (*B*), 250° F. (*C*), and 300° F. (*D*). Magnification ×375.**

**Relation between second-stage creep rate and ductility at fracture for high-purity copper tested in creep at different temperatures. The ductility at fracture does not necessarily increase continuously with increase in creep rate or with decrease in test temperature.**




*For further technical details, see* Creep of annealed and cold-drawn high-purity copper, *by William D. Jenkins and Thomas G. Digges, J. Research NBS* **47,** *272 (Oct. 1951) RP2154. For details of the earlier work with annealed copper, see* Creep of high-purity copper, *by William D. Jenkins and Thomas G. Digges, J. Research NBS* **45,** *153 (1950) RP2121; also, NBS Tech. News Bull.* **34,** *130 (Sept. 1950). Creep studies of ingot iron and of high-purity aluminum are described in NBS Tech. News Bull.* **34,** *34 (Mar. 1950) and* **35,** *43 (Mar. 1951), respectively.*

However, creep does not always conform to this idealized picture.

NBS found that, for the cold-drawn copper, the shape of the extension-time curves was similar to that previously observed for annealed copper, high-purity aluminum, and ingot iron. Deformation in the second stage of creep was discontinuous, the degree of discontinuity being affected by test temperature and stress. However, no simple or consistent relation was found between the ductility of the cold-drawn copper and the time required to attain either the third stage of creep or complete fracture.

Curves showing the relation between stress and second-stage creep rate, for both the annealed and cold-drawn conditions, were not linear when the experimental results were plotted either on log-log or semi-log coordinates.

At each test temperature, the cold-drawn copper was markedly superior to the annealed copper in resistance to creep and to fracture. This superiority in strength, however, was accompanied by a considerable loss in elongation at fracture; for equivalent second-stage creep rates and temperatures, reduction of area at fracture was about the same for both forms of copper.

Metallographic study of the specimens after testing in creep confirmed the previous finding that several modes of deformation occur during the creep tests. For similar test conditions, the number and size of the subcrystals observed in the region of the fracture were decreased by cold-drawing the copper prior to testing in creep. Furthermore, cold-drawing the copper appeared to alter the condition under which transcrystalline and intercrystalline fractures occur; transcrystalline fractures predominate at higher temperatures and slower creep rates for the cold-drawn than for the annealed copper.

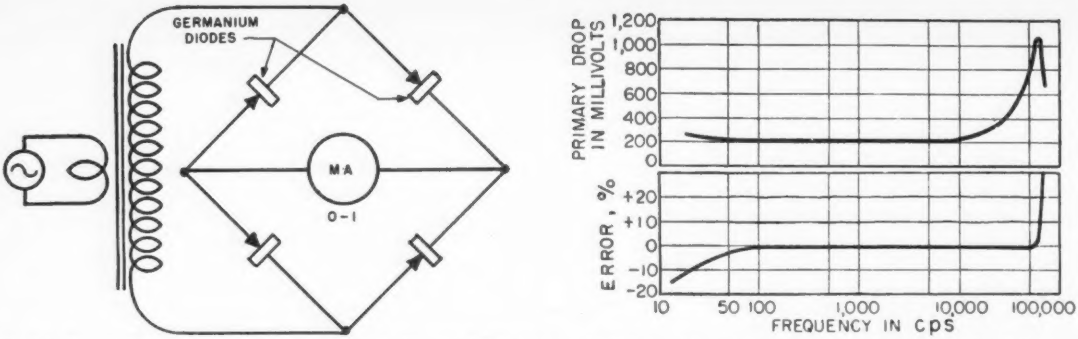
# Current Transformers for Audio Measurements

CURRENT transformers with rectifier-type ammeters connected to their secondaries have often been used to measure heavy currents at power frequencies. With the availability of modern crystal diodes, the method becomes suitable for lower currents and for a wider range of frequencies. It is being used to advantage in the NBS electronics laboratory for audio-frequency currents of the order of 1 to 3 amperes over a range of 50 to 50,000 cycles per second.

The method has several attractive features. The scale is nearly linear, the instrument can withstand substantial overloads without injury, and the power required is less than for thermal-type ammeters.

Such an audio-current metering system is rather readily improvised. In one successful version at NBS, the transformer was made by winding from one to three turns of wire around the outside of an ordinary replacement-type filter choke, the core laminations of which were interleaved to give low reluctance and thus low magnetizing current. This gave a transformer ratio of the order of 1 to 1,000 and a secondary inductance of about 40 henries. Four 1N34 crystal diodes and a 1-milliampere 50-ohm meter were used for rectification and indication. The effective current ratio was adjusted by changing the number of primary turns and by shunting the indicating instrument. Shunting the secondary winding is in general permissible; shunting the primary is not.

For good low-frequency response, the secondary reactance must be high compared to the total direct-cur-




**(Left) Current transformers making use of crystal diodes are being used to advantage in NBS laboratories for measuring audio currents over a wide range of frequencies. (Right) Frequency response of the transformers is essentially flat from below 100 cycles to above 50,000 cycles.**

rent resistance in the secondary circuit. Flat high-frequency response is favored by using high-permeability core material and reducing the number of secondary turns to the minimum required for the necessary inductance, thus reducing distributed capacitance. In the model described, low-frequency response was down about 5 percent at 50 cycles. High-frequency response was essentially flat to 50 kilocycles, but rose rapidly to a resonance peak near 100 kilocycles.

*For a somewhat fuller note on this subject, see* Current transformers for audio measurements, *by Lawrence T. Fleming, Electronics* **24**, *No. 7, 188 (July 1951).*

# NBS Symposia and Society Meetings

## Evaluation of Optical Imagery

A SYMPOSIUM on the Evaluation of Optical Imagery, held at the National Bureau of Standards on October 18, 19, and 20, 1951, was attended by approximately 250 specialists in this field. Sponsored by NBS in cooperation with the Office of Naval Research, the meeting was the ninth of 12 symposia scheduled for the Bureau's semicentennial year. The program, under the chairmanship of Dr. I. C. Gardner of NBS, consisted of 21 technical papers organized to treat comprehensively a phase of lens design which is of great importance to the designer but which has not yet received complete, systematic treatment in any one publication.

In applied optics, lens designs are usually evaluated on the basis of geometric optics, and the performance of optical systems is commonly measured in terms of their geometic aberrations. These practices are justified when aberrations are so large that diffraction plays but a small part in determining the quality of the imagery. Now, however, better optical systems are being produced, automatic computing machines make it possible to test an optical design completely by computation, the interferometer enables the wave front emergent from an optical system to be completely mapped, and integrating devices permit diffraction effects to be readily and fully determined. The purpose of the symposium was to reexamine and compare the present methods of image evaluation in the light of recent developments, with the purpose of placing these methods on a sound engineering basis and utilizing the principles of physical optics when justified. It is expected that the proceedings, including both papers and discussion, will be published as a single volume.

The six sessions of the symposium were under the chairmanship of Dr. I. C. Gardner (NBS), Dr. W. R. Brode (NBS), Dr. H. R. J. Grosch (International Business Machines), Dr. A. Maréchal (Institut d'Optique, Paris), Professor S. S. Ballard (Tufts College), and Professor Brian O'Brien (University of Rochester), respectively. The meeting began with a paper by Professor F. Zernike (Natuurkundig Laboratorium, Gronnigen, The Netherlands) on the diffraction theory of aberrations. Tolerances for various aberrations were given; they are much larger than expected from geometric optics. Dr. Maréchal discussed the quality of optical images as determined by various quantities related to the diffraction pattern. Primary diffraction images produced by fully corrected objectives of high numerical aperture were treated by Dr. Harold Osterberg and R. A. McDonald (American Optical Co.).

The bases for testing optical instruments were outlined by Dr. L. E. Howlett (Canadian National Research Council). Dr. D. E. Macdonald (Boston University) discussed the quality aspects of the aerial photographic system, describing an experiment whereby the resolution, scale, and contrast relations that allow for detection recognition of basic forms can be evaluated and discussed. Dr. M. Herzberger (Eastman Kodak Research Laboratory) presented a mathematical analysis of the image errors of a given optical system for different focal settings in terms of the new image

theory for finite aperature and field. It was shown that this theory is of value to the lens designer, as it gives a graphical picture of the contributions of the single construction element to the finite image. Professor A. Arnulf (Institut d'Optique, Paris) gave a short description of the apparatus built at the Institut d'Optique for standard checking of quality and performance of optical instruments under conditions closely approximating those occurring in actual practice. Results were also given concerning the effects of absorption, stray light, single aberrations, and the choice of the tests.

A comparison of image quality evaluations by different test methods for telescopic systems was presented by Dr. H. S. Coleman (Bausch & Lomb Optical Co.). Professor A. C. S. van Heel (Der Technische Hogeschool, Delft, the Netherlands) discussed applications of Fresnel diffraction to measurements of high precision. By observation of the colored diffraction patterns produced by gratings with periods of about 0.5 millimeter, the parallelism and the structure of light pencils can be studied with a precision corresponding to deviations in the wave front of well below one-fiftieth of a wavelength. Dr. J. G. Baker (Harvard College Observatory) presented a progress report on several phases of a combined laboratory and computational approach to the problem of realizing optimum compromises in the design of photographic lenses. The study involves the computation of a number of large lens systems, laboratory testing, and the preliminary use of objective types of test targets. Dr. G. Toraldo (Instituto Nazionale di Ottica, Florence, Italy) discussed the geometrical and interferential aspects of the Ronchi test.

Dr. Erik Ingelstam (Royal Institute of Technology, Stockholm, Sweden) described a method, developed by Dr. J. Lindberg and himself, which includes the measurement of photographic resolving power and distortion, and the determination of field curvature in a single photographic record. The essential feature of the method is the use of a "tilted test plate" with line groups in the collimator. Dr. R. E. Hopkins, Thomas Lauroesch, Vance Carpenter, and Howard Kerr (University of Rochester) discussed two methods that have been tried out in their laboratory for measuring the energy distribution in optical images. The use of automatic computing machinery at NBS in optical-ray tracing calculations and the computation of image coefficients was discussed by D. P. Feder (NBS).

Dr. F. E. Washer (NBS) described a new variable-contrast resolving power test chart recently developed at NBS; this chart enables the user to obtain in a single photograph a complete record of the resolution characteristics of a lens over a wide range of contrast (see p. 8). The theory of resolving power as applied to sine-curve test objects was developed by Dr. E. W. H. Selwyn (Kodak Limited Research Laboratory), who also described some interesting experiments using sine-curve test objects. Otto H. Schade (Radio Corporation of America) presented a new theoretical approach for evaluating lens performance for television purposes and demonstrated a machine developed for the Office of Naval Research by means of which this method is automatically applied to a lens.

Dr. Brian O'Brien (University of Rochester) gave an interesting paper on his recent work on the resolving power of the retina of the eye, in which he has been able to eliminate the effect of the spherical aberration of the eye in assessing resolving power. The position of the best focus of a lens in the presence of spherical aberration was discussed by R. Kingslake (Eastman Kodak Co.) from the standpoint of both the designer and the user of the lens. The technique of image evaluation by edge gradients was outlined by Arthur Cox (Farrand Optical Co.). R. V. Shack (NBS) described experiments in which the dependence of resolving power on object contrast in a photographic system was investigated. He also presented a method of determining image quality in which the concept of resolution as such is not used.

The National Bureau of Standards has carried on a broad program of research and development in applied optics since its founding in 1901. Over the past 50 years, this program has resulted in the establishment of procedures for measuring and specifying the characteristics of photographic lenses, the development of military optical fire-control devices and methods for testing them, the construction of very large optical elements for supersonic wind tunnels and astronomical work, and the development of methods of high-precision refractometry and standards of refractivity for use in the food, paint, drug, and other industries. Activity in this field at NBS has recently been intensified as additional projects have been undertaken for the armed services.

## Polymer Degradation Mechanisms

THE MECHANISMS of polymer degradation were the subject of a symposium held at the National Bureau of Standards on September 24, 25, and 26, 1951. This was the eighth of a series of 12 symposia scheduled for the year 1951, which marked the fiftieth anniversary of the Bureau's establishment. Sponsored by NBS in cooperation with the Office of Naval Research, the meeting brought together approximately 200 scientists from this country and abroad who are engaged in theoretical and experimental studies of the manner in which plastics break down on exposure to light, heat, moisture, and other deteriorating influences. Seventeen technical papers were presented by representatives of government, industry, and the universities.

Research on the durability of polymeric materials is becoming increasingly important as these materials take on new uses and find application in national defense. A knowledge of the mechanisms by which polymers degrade is needed in order to predict more accurately their expected service life, to inhibit degradation more effectively, and to devise better methods of accelerated testing. Among the plastics discussed at the

symposium were nylon, saran, polyvinyl chloride, polyacrylonitrile, polyethylene, polystyrene, and the cellulose esters and ethers. Although these materials show a high degree of stability and last much longer in most applications than the natural products that they have replaced, a better understanding of how and why they fail should lead to an even greater degree of permanence.

The first session, under the chairmanship of Dr. G. M. Kline (NBS), was concerned with the fundamental theories of degradation. Dr. H. H. G. Jellinek, (University of Adelaide, Adelaide, Australia) presented his theories of random degradation, weak link, and preferential degradation from chain ends involving initiation, propagation, and termination steps. Dr. R. Simha showed that the photochemical and pyrolytic degradation of vinyl polymers is a complicated process that cannot in general be described by a theory of random breaking of links. Since free radicals are involved, it is natural to treat these reactions as the reverse of an addition polymerization, that is, as chain reactions. The simplest mechanism consists of an initiation of free radicals, followed by propagation, transfer, and termination steps. Dr. Simha pointed out that two parameters are important: the kinetic chain length and the probabilities of transfer and initiation.

**American Physical Society**

**Congratulatory scroll presented to NBS by the Society in commemoration of the Bureau's fiftieth anniversary.**

# The American Physical Society

to the

# National Bureau of Standards

## GREETINGS

The Council of the American Physical Society extends to the National Bureau of Standards its felicitations on the completion of fifty years of outstanding service to the science of physics in all of its aspects, in all of its departments, and in all of its applications. Since its foundation the National Bureau of Standards has been one of the most notable institutions in the promotion of physics, and this not merely in the United States but in the entire world. The Council also remembers with gratitude and affection the nearly fifty occasions on which the National Bureau of Standards has been host to the American Physical Society affording it as many opportunities of meeting under the most pleasant of conditions and with the most admirable collaboration from the staff of the Bureau. These occasions have also given to the members of the Society wonderful opportunities for becoming acquainted with the staff of the Bureau and with its excellent work. The Council hopes and expects that the National Bureau of Standards will continue to flourish perpetually, and steadily to increase the debt which is already owed to it by all physicists of the United States and of the world. In these congratulations and in these expectations, the Council is confident that it expresses the feelings of the entire membership of the American Physical Society.

*Given at the meeting held by the Council of the American Physical Society at the National Bureau of Standards on the 26th of April, 1951*

Charles C. Lauritsen
President
John H. Van Vleck
Vice-President
Karl K. Darrow
Secretary
George B. Pegram
Treasurer

A paper on "The photochemical degradation of polymethyl methacrylate", by P. R. Cowley and Professor H. W. Melville of the University of Birmingham, Birmingham, Eng., was read to the group by A. R. Burgess (Imperial Chemical Industries, Ltd.). It was shown that polymethyl methacrylate degrades rapidly to the monomer when irradiated with ultraviolet light of wavelength 2537 Angstroms in vacuum at temperatures above 130° C. The degradation is a true depolymerization process involving initiation, propagation, and mutual termination. Information on the degradation of this polymer is of special value, inasmuch as it is one of the most stable polymeric materials.

The second and third sessions dealt with the degradation of polyvinyl chloride-type polymers. Papers on "The effect of heat and light on polyvinyl chloride", by D. Druesedow and Dr. C. F. Gibbs (B. F. Goodrich Chemical Co.), and "The photodegradation of polyvinyl chloride," by Dr. A. S. Kenyon (Monsanto Chemical Co.), were presented at the second session, which was under the chairmanship of Dr. B. S. Biggs (Bell Telephone Laboratories).

Dr. J. B. Nichols (E. I. duPont de Nemours & Co.) was chairman of the third session. A. L. Scarbrough, W. L. Kellner, and P. W. Rizzo (National Lead Company Research Laboratories) reported on "The role of hydrogen chloride in polyvinyl chloride degradation", and C. B. Havens (Dow Chemical Co.) discussed the "Aging of vinyl chloride and vinylidene chloride polymers". Loss of hydrogen chloride occurs during degradation of these polymers and must be inhibited; however, the initiation mechanism is not yet clearly defined. Work on polyvinyl chloride at NBS, reported in the discussion period by B. G. Achhammer (NBS), suggests that the initiation step is caused by the breakdown of hydroperoxide in the polymer and that the correlation usually drawn between loss of hydrogen chloride and discoloration of the polymer is questionable.

In a paper by Dr. J. R. McCartney (E. I. duPont de Nemours & Co.), polyacrylonitrile was reported to undergo rapid and large molecular weight degradation on addition of dilute alkali to its solutions. Application of the theoretical considerations of Montroll and of Simha to this work suggests that the reaction mechanism is a random chain scission of the normal head-to-tail polymer linkages.

The mechanism of oxidation of polyethylene and its stabilization was described in the fourth session, which was under the chairmanship of C. R. Stock (American Cyanamid Co.). Dr. B. S. Biggs (Bell Telephone Laboratories) discussed "Studies on the oxidation of polyethylene", and A. R. Burgess (Imperial Chemical Industries, Ltd.) described the "Photooxidation and

stabilization of polyethylene". The susceptibility of this polymer to photooxidation when unprotected makes its useful life in outdoor exposure very short. However, light-absorbing pigments, such as carbon black, increase the life of the material by as much as 10 years or more. Professor J. R. Shelton (Case Institute of Technology) showed that the rate of oxidation of phenyl-substituted olefins is a function of the concentrations of peroxide and unreacted olefin. Oxidation at the alpha methylene group is indicated, although some initial attack at the point of unsaturation also seems probable.

The fifth session, of which Dr. R. B. Mesrobian (Polytechnic Institute of Brooklyn) was chairman, consisted of two papers on the "Breakdown in cellulose ester systems by heat and light", by G. C. DeCroes and Dr. J. W. Tamblyn (Tennessee Eastman Co.), and the "Oxidative degradation of ethyl cellulose", by Dr. L. F. McBurney (Hercules Powder Co.). Emphasis was placed on the oxidation mechanisms of the cellulosic polymers. Apparently the primary attack by oxygen forms hydroperoxide, and the secondary reactions, such as those causing a drop in viscosity, result from the hydroperoxide decomposition.

The final session, under the chairmanship of Dr. Warren Stubblebine (Office of the Quartermaster General), summed up the research on degradation mechanisms at NBS. Dr. S. L. Madorsky (NBS) discussed the rates of thermal degradation of polystyrene and polyethylene that were obtained by measuring the loss in weight of samples by means of a very sensitive tungsten spring balance enclosed in a vacuum. Rate curves plotted against percentage degradation indicate that in the case of polystyrene the process is intermediate between a zero- and a first-order reaction, while in the case of polyethylene, the process resembles a first-order reaction. Activation energies were calculated on the basis of rates of degradation at various temperatures. Dr. L. A. Wall (NBS) described the pyrolysis of copolymers. Studies on styrene-butadiene, styrene-isoprene, and methyl methacrylate-isoprene copolymers led to the derivation of expressions relating the yield of each species to its value from the simple polymer, to the copolymer composition, and to the reactivity ratios of the monomers involved in the preparation of the copolymer. The relationships derived are applicable to any process occurring at the boundaries of the sequences and may be useful in studies of other types of degradation.

Since 1946, the Office of the Quartermaster General has supported an NBS project on the mechanism of polymer degradation. Two phases of this work were reported during the final session. B. G. Achhammer (NBS) discussed the degradation of polystyrene by heat and ultraviolet radiant energy. The importance of hydroperoxide, which is assumed to be the result of primary attack on the polymer by oxygen, was demonstrated. The results of this work show that the degradation of polystyrene involves two different processes: (1) the breakdown of thermolabile groups formed in the polymer prior to degradative treatment (this is caused by exposure both to heat and to ultraviolet radiant energy at 120° C and is accompanied by the removal of residual materials such as solvent), and (2) the oxidation of the polymer (caused by exposure to ultraviolet in the presence of oxygen at 120° C.) The mechanism of the degradation of polyamides was reported by F. W. Reinhart (NBS) as consisting of the following steps: (1) breaking of the polymer molecules at the C-N bond of the peptide group; (2) changes in the degree of crystallinity or local order; (3) changes in the amount of strongly bound water, organic liquids, or both.

The most striking aspect of the conference was the progress that appears to have been made over the past few years in elucidating the structure of polymers and the mechanisms of their breakdown. The insight thus provided into the fundamentals of the degradation reactions should aid materially in the solution of some of the problems of polymer degradation in the near future. To make the results reported at the symposium generally available to workers in the field, NBS plans to publish the proceedings, together with discussions and submitted comments.

## Institute of Mathematical Statistics

THE FORTY-NINTH meeting of the Institute of Mathematical Statistics was held in Washington, D. C., on October 26 and 27, 1951. Over 350 members attended the sessions, heard 15 contributed papers and two invited addresses, and witnessed a demonstration of the National Bureau of Standards Eastern Automatic Computer—SEAC.

The meeting was divided into eight sessions, the first of which was presided over by Dr. Eugene Lukacs (NBS). Six papers were presented on such topics as the law of propagation of error, multivariate orthogonal polynomials, analysis of variance for paired comparisons, statistical theory of fatigue failures, chain block designs, and results of some tests of randomness on pseudo-random numbers. Following this session was one on the planning of experiments, Miss Besse B. Day (U. S. Naval Engineering Experimental Station) presiding.

The Friday-afternoon session was devoted to an invited address by Dr. Herbert Solomon (Office of Naval Research) on the ONR Program in Probability and Mathematical Statistics. A tour of selected NBS laboratories was also conducted during the early afternoon. Later, the second invited address on "Recent developments in acceptance-sampling theory and practice" was presented by Professor A. H. Bowker (Stanford Univ.) in a session held jointly with the Washington Section of the American Society for Quality Control.

The first Saturday morning session was devoted to probability and mathematical statistics, at which time five papers pertaining to this subject were presented. Professor J. W. Tukey (Princeton Univ.) presided over

the second which dealt primarily with statistical inference.

Dr. J. H. Curtiss, Chief of the NBS National Applied Mathematics Laboratories, was chairman of the Saturday afternoon session. Dr. A. V. Astin, Acting Director of the National Bureau of Standards, gave the welcoming address and was presented with a commemorative scroll by Dr. T. W. Anderson on behalf of the Institute. The scroll congratulates the National Bureau of Standards "for its outstanding accomplishments in mathematics, science, and engineering, and their application to the furtherance of the public welfare. In particular, the Institute commends the Bureau for the excellence of its research in Mathematical Statistics, fundamental and applied; and for the vigor and skill with which it has employed statistical method in evolving more accurate and economical procedures for scientific research and engineering operations".

# Publications of the National Bureau of Standards

### Periodicals

Journal of Research of the National Bureau of Standards, volume **47**, number 6, December 1951 (RP2268 to RP2278, incl.).

Technical News Bulletin, volume **35**, number 12, December 1951. 10 cents.

CRPL–D88. Basic Radio Propagation Predictions for March 1952. Three months in advance. Issued December 1951. 10 cents.

### Research Papers

*Reprints from Journal of Research, volume* **47**, *No. 5, November 1951*

RP2259. Mass spectra of some organo-lead and organo-mercury compounds. Vernon H. Dibeler and Fred L. Mohler.

RP2260. Resolution of the dissociation constants of d-tartaric acid from 0° to 50° C. Roger G. Bates and Richard G. Canham.

RP2261. Effect of $SO_3$ on the alkali compounds of portland cement clinker. Terry F. Newkirk.

RP2262. Resin bonding of offset papers containing mineral fillers. Martin J. O'Leary, Bourdon W. Scribner, and Joshua K. Missimer.

RP2263. A method for corn-sirup analysis involving selective adsorption. Emma J. McDonald and Roger E. Perry, Jr.

RP2264. Effect of exposure to soils on the properties of asbestos-cement pipe. Irving A. Denison and Melvin Romanoff.

RP2265. Photometric determination of copper in iron and steel with diethyldithiocarbamate. John L. Hague, Eric D. Brown, and Harry A. Bright.

RP2266. Description and analysis of the second spectrum of chromium, Cr II. Carl C. Kiess.

RP2267. Harmonic output of the synchronous rectifier. Paul Selgin.

### Circulars

C515. Energy and angle distribution of the photoprotons from deuterium. Martin Wiener. 15 cents.

### Handbooks

H49. Recommendations for waste disposal of phosphorus-32 and iodine-131 for medical users. 10 cents.

### Publications in Other Journals

The selection of a limited number from many possible conditioning treatments for alloys to achieve best coverage and statistical evaluation. J. M. Cameron and W. J. Youden. Proc. ASTM (1916 Race Street, Philadelphia 3, Pa.) **50**, 951 (1950).

Deterioration of silicate cements in the tropics. Theodore E. Fischer, Lieutenant Colonel, U. S. A. F., and Irl S. Schoonover (NBS). U. S. Armed Forces Medical J. (Armed Forces Medical Publishing Agency, Department of Defense, Washington 25, D. C.) **2**, 907 (June 1951).

Physics. Measure for measure: Some problems and paradoxes of precision. Francis B. Silsbee. J. Wash. Acad. Sci (Mt. Royal and Guilford Aves., Baltimore 2, Md.) **41**, 213 (July 15, 1951).

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